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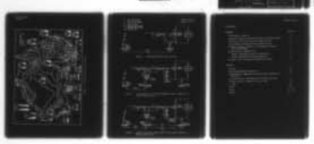

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Following a violent thunderstorm, widespread damage occurred to terminal equipment connected via an underground cable distribution system to the W.R.E. Computer.

This memo summarizes the results of investigations undertaken into available equipment and techniques which can be utilized to prevent similar damage in future thunderstorms.

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Following a violent thunderstorm, widespread damage occurred to terminal equipment connected via an underground cable distribution system to the W.R.E. Computer.

This memo summarizes the results of investigations undertaken into available equipment and techniques which can be utilized to present similar damage in future thunderstorms.

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1. INTRODUCTION

As a result of the widespread damage that occurred to terminal equipment connected to the W.R.E. Computer cable network following a thunderstorm on 11th November, 1976, a meeting was held on 25th November, 1976 to review the effects, and to decide upon future preventive action. PO/TE was asked to investigate and advise on protective measures.

The following report summarises the results of the investigations made with the assistance of Telecom Australia, the latest available documentation both local and overseas (see References), and discussions with local representative of protection equipment suppliers.

2. BACKGROUND TO PROBLEM

With the recent introduction of solid state data terminal equipment on communications circuits, it has become necessary to re-assess and modify previously satisfactory protection measures, since transient potentials exceeding 10 V peak at the equipment may now cause failure.

In the W.R.E. Computer network remote computer terminals are connected by multipair underground cable to the centrally located computer. It appears that the damage sustained in November was due to lightning strikes in the vicinity of the network that induced surges in some cables, either by induction or by causing earth potential gradients between the strike area and the terminal earth systems.

Field studies undertaken overseas into the effect of thunderstorms on underground cables show that a lightning strike to ground creates a broad front of electromagnetic disturbance that can induce potentials up to 1000 V (peak) in adjacent conductors and cause a longitudinal surge along the transmission line. The characteristic of the induced surge is a rapid rise to a peak value and a slower decay, typically a peak of 1000 V with a rise time of 10 μs and decay time to half peak of 1000 μs(ref.6). Because of the effect of attenuation in the conductors, terminal equipment is not usually exposed to wave fronts in excess of 500 V per μs. A severe lightning strike causing a 10 x 600 wave (10 μs to crest and 600 μs to half crest) could result in a peak current of more than 1000 A in a protector(ref.1). The surges on the transmission line are primarily longitudinal, but, because of circuit unbalance and asymmetric operation of protective devices, metallic or transverse surges will occur in a probable ratio of 9 to 1.

With reference to the earthing of equipment and cable sheaths, all parts of any combination of systems, including power sources and building should be connected to a low impedance common ground. Wiring between remote parts of a transmission system should be preferably carried in shielded cables with the shield connected to ground at both ends. Where cable shielding to ground is irregular and of high resistance the lightning induced currents will flow an increased distance to ground and increase the core to sheath voltage.

3. PROTECTIVE DEVICES APPLICABLE TO THE LOCAL PROBLEM

Protective devices applicable to the local problem are briefly as follows:

(a) The spark gap operates at atmospheric pressure but the operating potential is variable. A minimum practicable gap will spark over at a potential of 1000-1500 V, with a sustained arc potential of the order of 20 V.

(b) The gas tube is a spark gap enclosed in a rare gas at reduced pressure. A choice of gap settings and sparkover voltage is available from 90 V up. It has an inherent low arc resistance with some limitations in steady heavy current absorption. Some are designed to fail safe, i.e. to short circuit on overload.

(c) Carbon Blocks with set air or sealed gaps are available that sparkover at 500-600 V. The arc voltage is about 25 V and when the current rating is exceeded the blocks will short circuit.

(d) The Atmite block, similar in construction to the carbon block is equivalent to a non-linear resistor. Surface sparkover occurs at 500 V and the arc voltage is 50 V.

(e) Non-linear resistance elements of selenium, silicon carbide and metal oxide, are now available. These devices are voltage dependent resistors. When exposed to high energy voltage transients the varistor impedance changes from a very high standby value to a very low conducting value, thus clamping the transient voltage to a safe level. However the clamping voltage does increase slightly with increasing current. The Varistor is one of the more successful developments for transient suppression with a resistance differential of 10^8 to 1 and will restore to enable repeated operation. Varistors having trigger voltages between 50 and 1000 V and with a current dissipation in the order of 1000 A for 7 μs are available.

(f) The Silicon Controlled Rectifier can be used as a voltage clamp but the surge current capacity is relatively low. It tends to maintain conduction if a small follow on current is present, and it also requires a separate trigger circuit.

(g) Diodes used in the forward conduction mode will clamp at low voltages typically 500 mV for silicon and 300 mV for germanium, and are series connected to achieve the required voltage.

(h) Zener Diodes are used in the avalanche mode and will clamp at specified voltages. However, current surge limitations must be considered.

4. PROTECTION OF TERMINALS FROM TRANSIENT SURGES IN TWISTED PAIR CABLES

The level of protection to be provided, can be chosen between two extremes. One proposed in the US ECOM (ref.1 and Figure 1) recommends four stages of protection. On the other hand it has been ascertained that experience by other authorities using data modems in this area of South Australia is that zener clamps on the interface card, in conjunction with the inherent line attenuation, have so far proved adequate.

The level of protection needed at any installation will depend on the fortuitous nature of lightning strikes, height of ground and structures and soil resistivity.

The Isoceraunic level (average number of days of thunderstorm activity annually) of this area is a comparative low (10-15). See figure 3.

The majority of the W.R.E. Computer network cables have an aluminium alloy moisture barrier, continuity of which is maintained at joints. This barrier is earthed only at Labs 73 and ground insulation is otherwise high by virtue of the plastic ducting and the isolation of joints and cable bearers, so that high core to sheath voltages could be expected from near lightning strikes(ref.9 p.6). There is no evidence to show that damage sustained so far by W.R.E. equipment was caused by other than relatively small voltage transients, longitudinally propagated along cable pairs to ground via the affected circuitry.

To protect against the worst forseeable transients, at least two stages of protection are required (see figure 2).

(i) Primary protection to dissipate a high energy surge can be given by gas discharge tubes. For paired cable the AEI Type 16A is suitable. It is a 3 electrode tube that will ground both wires simultaneously when either conductor reaches arc potential and will limit longitudinal and transverse currents. These arrestors should be installed as near to the cable entry as possible and can be accommodated on the Main Distribution Frame (MDF) in Labs 73.

(ii) Limiting of peak surges at the equipment can be achieved by zener diodes. A diode pair back to back connected from each wire of a pair to earth will clamp a transient of either polarity. Zener diodes type IN3825N (4.7 V) would limit peaks to a tolerable level without affecting normal signals. To be effective, connection must be made as close as possible to the equipment to be protected as well as to the relative signal earth and preferably on the same circuit card. As it may not be possible to fit zeners on the IBM card the diodes could be installed at the connecting card interface, but a short, low resistance connection to the LDA signal earth would have to be provided.

Series resistance between the two stages is required to limit the zener current below breakdown. Resistor Catalogue No. 5905-99-014-0419 (27 Ω 6 W) would be suitable and would have negligible insertion loss in the 600 Ω line. These resistors could be installed at the M.D.F.

An improvement to the 2 stage protection indicated above would be the insertion of an intermediate protection stage. This would consist of a varistor connected between each wire and earth. The varistor is a new device capable of clamping to voltages above 50 V and withstanding high current surges. Its speed of response, which is in the ns range, is superior to other suppression devices. The General Electric Type V24ZA4 would be suitable and could be installed on the M.D.F. Series line resistors between the gas arrestor and varistor would be required to limit the varistor surge current. (8.2 Ω 6 W Catalogue No. 5905-014-0407 are considered suitable).

5. PROTECTION OF TERMINALS FROM TRANSIENT SURGES IN COAXIAL CABLES

A number of IBM 3277 terminals of the W.R.E. Computer Network are connected by 95 Ω coaxial cable Type RG62A/U to the central computer. The cables are laid in underground plastic ducts in lengths up to some 550 m and the screens are insulated from earth throughout in accordance with IBM requirements.

There is a possibility of damage to terminal equipment from transient current surges in the cable due to lightning strikes or adjacent power faults.

Because of terminal circuit loading to earth, a strike near the cable run will cause induced longitudinal currents in core and screen, and the unbalance of cable screen to core and terminal equipment will result in transverse current surges. (See figure 4).

Protection circuits should prevent voltages in excess of some 12 V appearing at the terminal interface, whilst offering minimum attenuation to the normal signals of 4 to 7 V peak in 95 Ω over a frequency range from DC to 10 MHz.

Protection against the more probable hazard of low level transients is best achieved using back to back zener diodes with a rating between the maximum signal and minimum safety voltage levels. The method of connection will depend upon the IBM circuit configuration which is understood to have a floating screen. Zener diodes should be connected as close as possible to the protected interface, preferably on the same card. IBM have advised verbally that they will provide zener diode protection.

Protection against higher level transients with varistors is usually a practical and economic solution. However, in this case the varistor capacitance of 1 to 2nF would give a shunt impedance at 10 MHz approaching the circuit load and is not recommended.

IBM have advised that protection against high level voltage and current surges should be provided by W.R.E. by the use of the 3-electrode gas arrestor AEI Type 21[illegible] This has similar characteristics to the AEI Type 16A and either would be satisfactory. Advice from supply agencies to date reveals that suitable fittings for installation are available only for the Arrestor Type 16.

These 3-electrode arrestors will operate in 1 μs from strike voltages over 150-350 V depending on the wave front rise time and will then limit the potential on the terminal equipment to 30 V. A striking of either the core or the screen conductor will trigger the tube so that both conductors achieve equipotential in 0.1 μs and transverse currents are suppressed.

One arrestor is required for each coaxial terminal, connected as shown in figure 5. Input and output BNC connectors would allow easy installation and testing access to existing cables.

The gas arrestor should be installed as close as practicable to the building cable entry. In Labs 73 a multiple mounting can be fitted on the Main Distribution Frame.

To retard current fed to the lower level protection zener diodes a linear series resistor (4.7 Ω 6 W non-inductive) should be fitted. This could be accommodated with the gas arrestor fitting.

As previously stated, the zener diodes should be installed on the same card as the circuit protected. Any impedance between the protected circuit and its signal earth, or between the signal earth and gas arrestor earth can carry sufficient current under strike conditions to raise the potentials between them to circuit breakdown levels, e.g. a difference of earth resistance of 10 Ω with a typically low earth current of 10 A could cause a potential of 100 V in the protected interface (see figure 6). The arrestor and signal earths should therefore be connected by a low resistance link cable if IBM circuit conditions permit.

6. CONCLUSIONS

The minimum required protection on twisted pair cable circuits can be provided by zener diodes on the circuit card. Four diodes are required for each 2 wire terminal at an approximate component cost of $1.00 per diode.

Protection against high voltage line surges on twisted pair cable circuits can be best given by 3 electrode gas filled surge arrestors connected to the cable termination. One arrestor is required for each 2 wire terminal at an approximate cost of $12.00 for arrestor and mounting.

Intermediate Protection for additional safety on twisted pair cable circuits can be provided by the insertion of varistors. Two varistors are required for each 2 wire terminal at a unit cost of approximately $1.50 per varistor. The cost of series resistors, 2 of which are required between the stages of protection, is approximately 20 cents each.

The minimum required protection on coaxial cable circuits can be provided by zener diodes on the circuit card. Two diodes are required for each coaxial terminal at an approximate component cost of $1.00 per diode.

Protection against high voltage line surges on coaxial circuits can be best given by 3 electrode gas filled surge arrestors connected to the cable termination. One arrestor is required for each coaxial terminal at an approximate cost of $12.00 for arrestor and mounting.

Detailed plans for installation can be finalised when a decision on the degree of protection required is made and the appropriate hardware has been ordered from the supplier.

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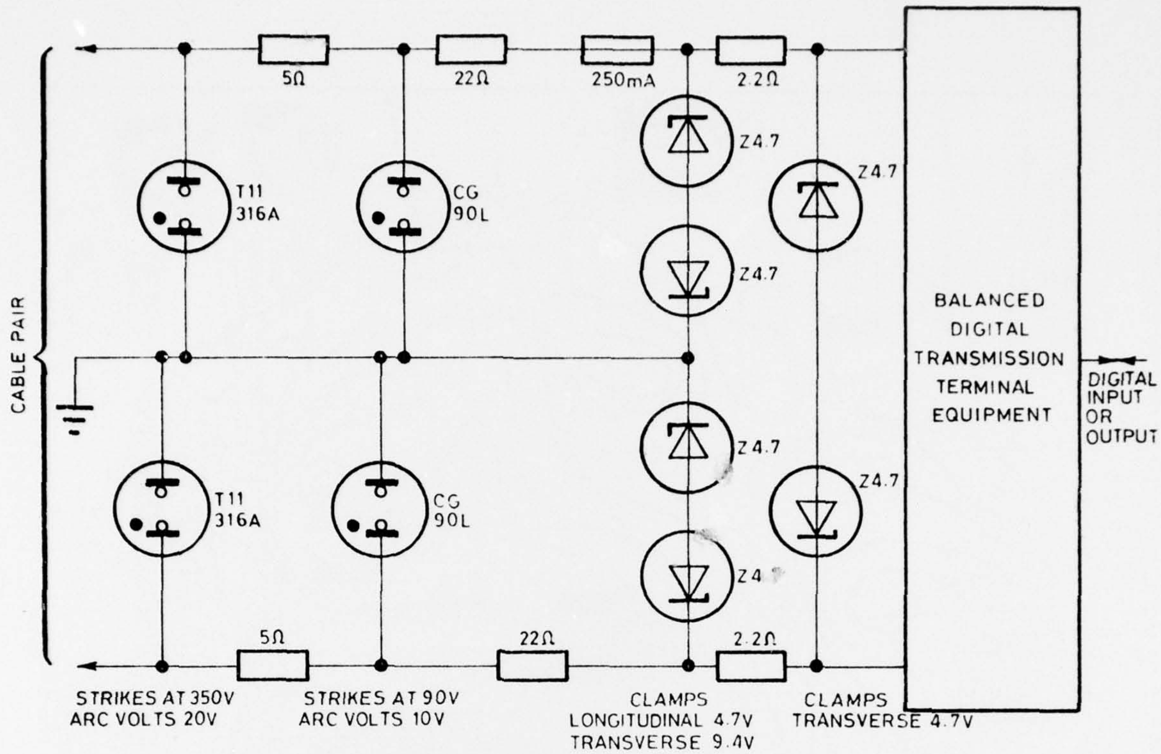

Figure 1. Line surge suppression. Example of 4 stage protection by U.S. ecom 1972.

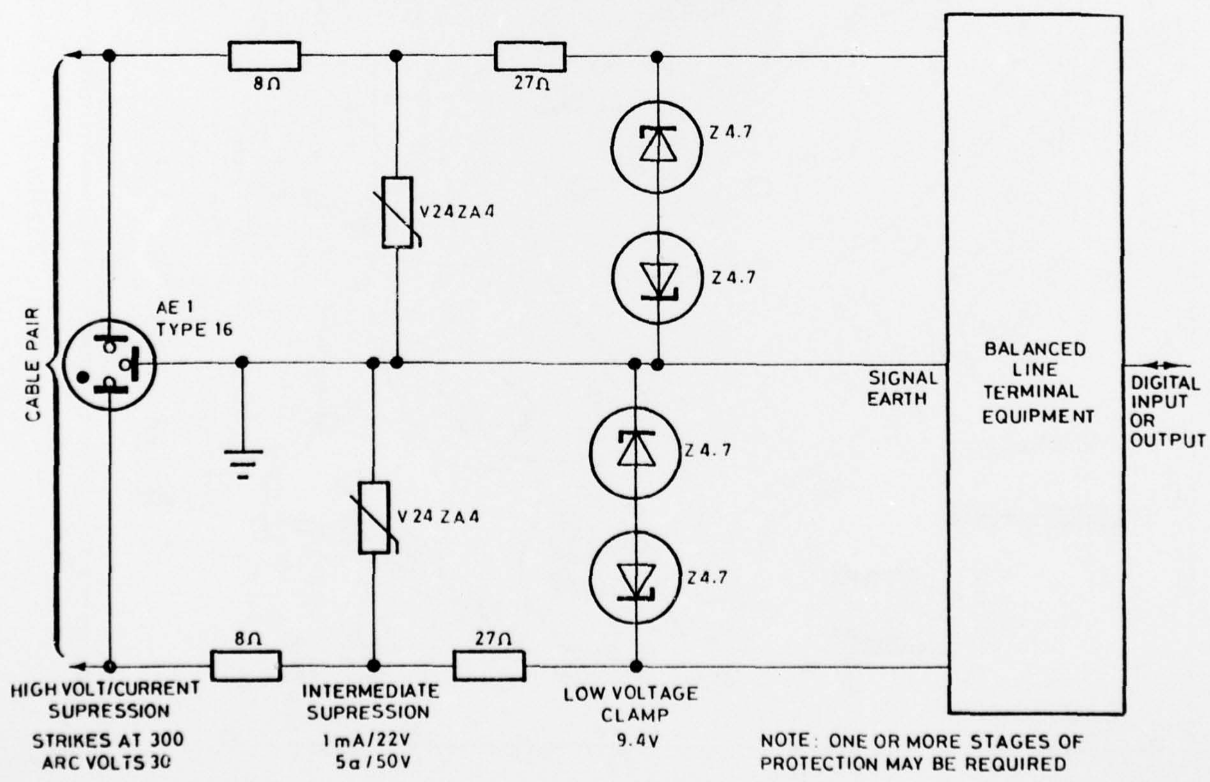

Figure 2. Line surge suppression. Three stages of protection.

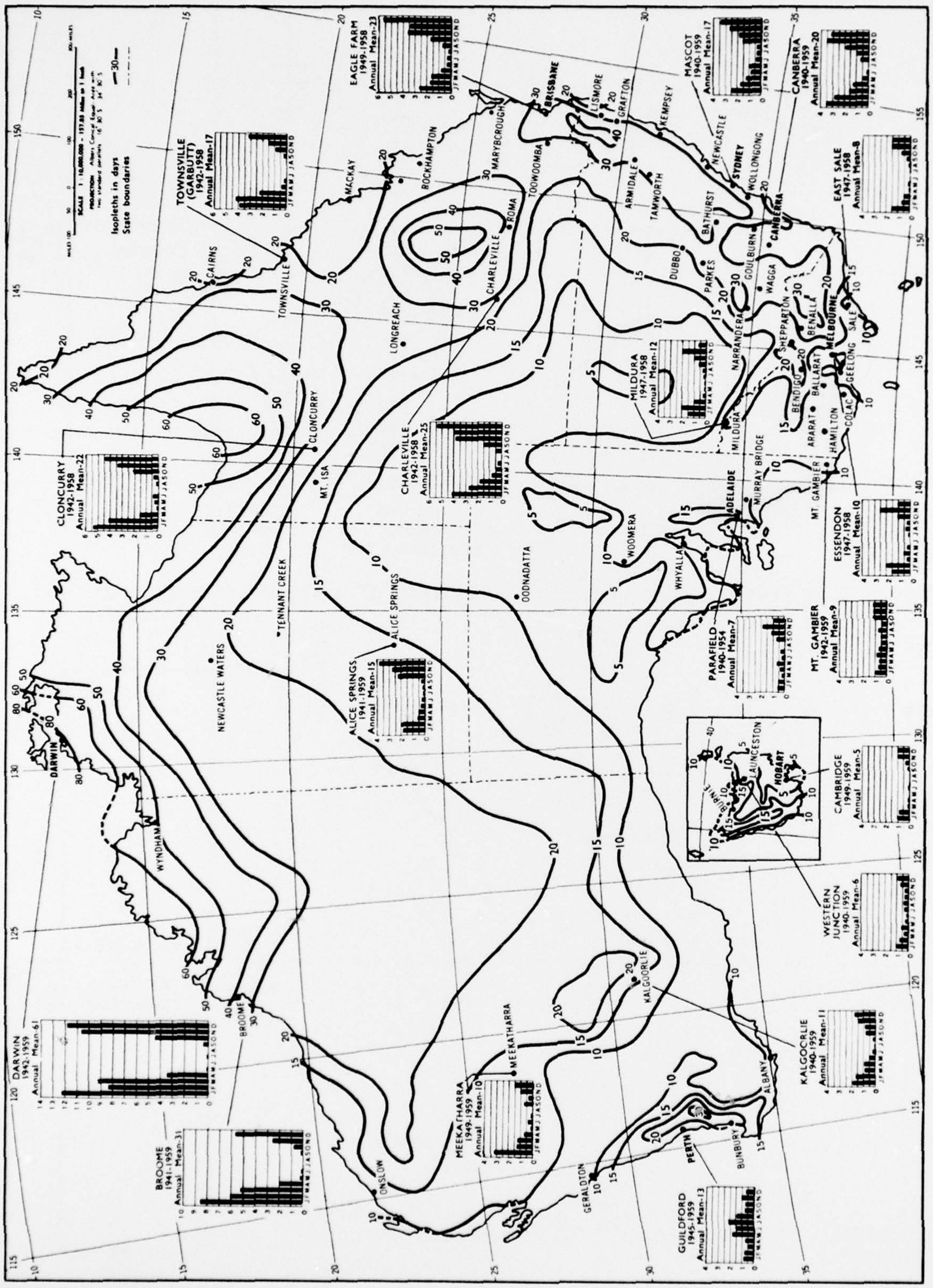

Figure 3. Isoceraunic levels in Australia.

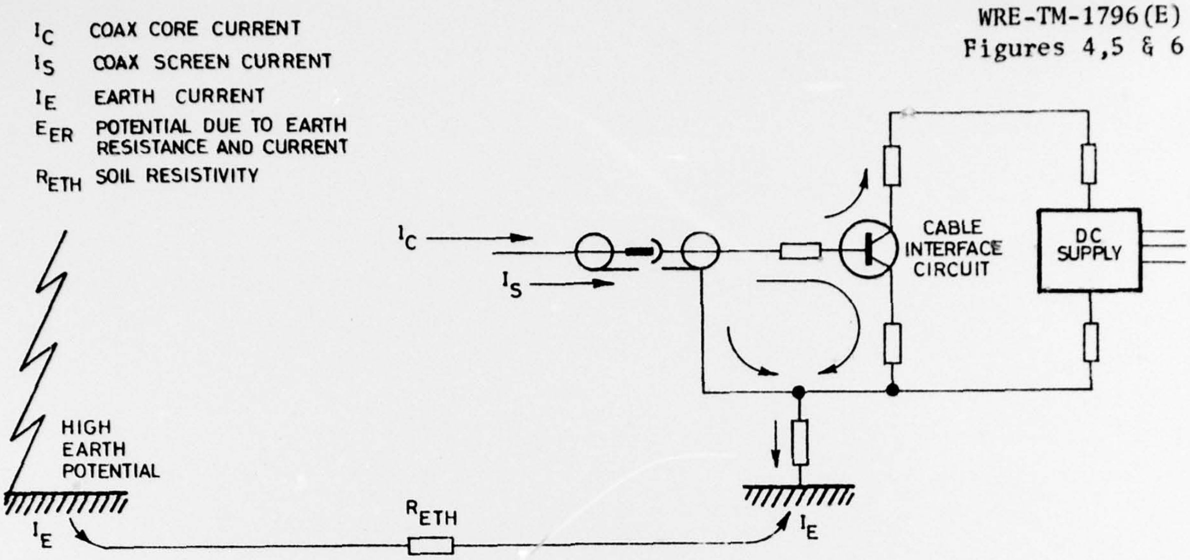

Figure 4. Unprotected coaxial cable circuit.

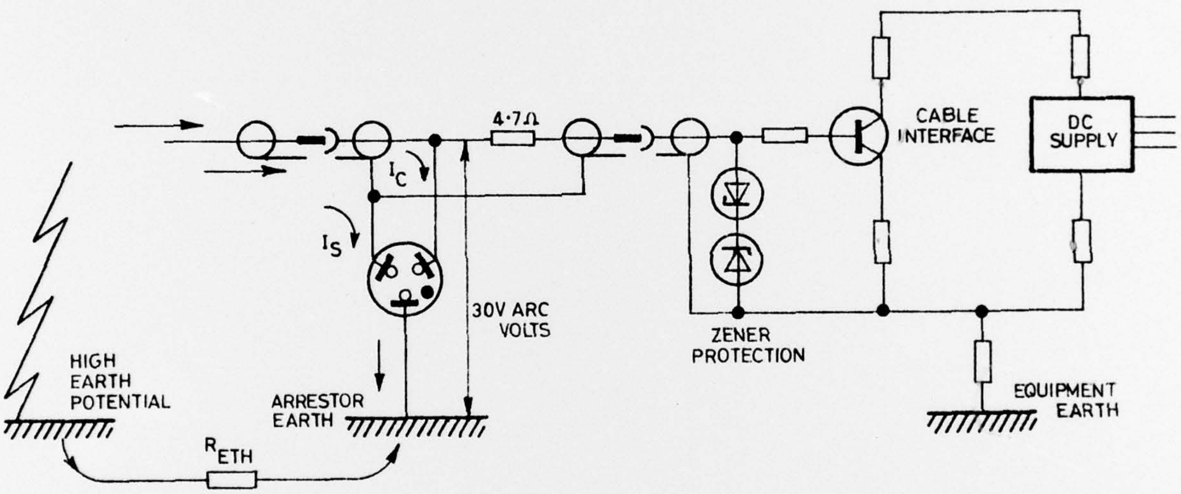

Figure 5. 3-electrode gas arrestor and example of zener connection in coaxial cable circuit.

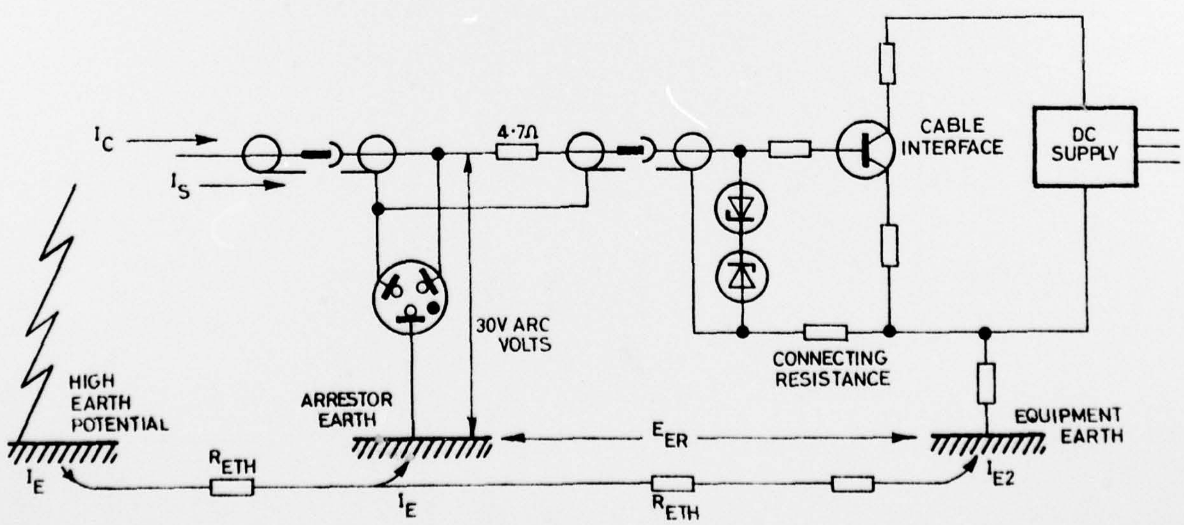

Figure 6. Hazard of incorrect zener location and separate earths in coaxial cable circuit.

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